

Recycling in Integrated Urban Adaptation Actions and Greenhouse Gas Mitigation: A Sustainable Approach for Climate Resilient Cities

Luciana Vilardo de Freitas Figueras¹ & Antonio Antonio Pasqualetto²

¹ Specialist in Executive Management in the Environment from the Alberto Luiz Coimbra Institute of Postgraduate Studies and Engineering Research, Federal University of Rio de Janeiro, Brazil

² Full Professor, the Pontifical Catholic University of Goiás and the Federal Institute of Education, Science and Technology of Goiás, Brazil

Correspondence: Luciana Vilardo de Freitas Figueras, Specialist in Executive Management in the Environment from the Alberto Luiz Coimbra Institute of Postgraduate Studies and Engineering Research, Federal University of Rio de Janeiro, Brazil.

Received: March 26, 2024

Accepted: May 8, 2024

Online Published: May 24, 2024

doi:10.5430/ijba.v15n2p66

URL: <https://doi.org/10.5430/ijba.v15n2p66>

Abstract

Cities face challenges due to climate change, including extreme weather events and increasing GHG emissions. In this context, recycling emerges as an essential tool to promote urban resilience, reduce carbon emissions, and promote a circular economy. Thus, the objective was to examine the role of recycling as an integral part of urban adaptation and greenhouse gas (GHG) mitigation strategies. The methodology included consultations with articles and legislation on the subject, as well as exploring examples of good practices from industries and effective policies that highlight the benefits of integrating recycling into adaptation and mitigation initiatives in cities. The results demonstrate the importance of effective recycling policies and practices to build climate-resilient cities and promote a transition to a low-carbon economy.

Keywords: cities, adaptation, mitigation, resilience, sustainability, recycling

1. Introduction

After recurring environmental catastrophes, the emphasis on climate issues in world geopolitics has generated urgency in reversing the growth of global greenhouse gas emissions and advancing actions that promote climate adaptation and mitigation. This was the focus of the Conference of the Parties composing COP 27, which took place at the end of 2022 in Egypt, with several debates regarding the energy aspect and its relationship with reforestation and green hydrogen.

Climate change poses a threat to urban areas, exacerbating the risks of extreme weather events, flooding, and resource scarcity. At the same time, cities are responsible for a substantial share of global greenhouse gas (GHG) emissions, mainly from energy consumption and waste management.

Some Brazilian cities were partly constructed in a disorderly way, with the absence of territorial planning and within the historical scenario of socioeconomic inequality, which promoted the conflict and urban segregation observed in the country's capitals, and included a marked housing deficit, environmental degradation and informal access to urban land (Rosin and Teixeira, 2013).

It is true to say that the socio-environmental vulnerability present in Brazilian urban areas is directly linked to climate change that affects populations living precariously in areas of risk, such as landfill sites in Brazil (Dos Santos and Pedroso Junior, 2021).

This agenda deserves to be explored, given its relevance for cities and its impact on the decarbonization of industrial activity, which is one of the largest contributors to the emission of greenhouse gases. This is what the IPCC did; looking at ecosystems, biodiversity, and human communities at the global and regional levels, with an emphasis on vulnerabilities and the capacities and limits of the natural world and human societies in adapting to climate change (Intergovernmental Panel ON climate change - IPCC, 2023).

In this sense, the management of urban solid waste generated by society has become a challenge and a generator of socio-environmental vulnerabilities. In 2022 alone, more than 81.8 million tons were generated in Brazil. This corresponds to 224 thousand tons per day, according to data from the latest Solid Waste Panorama, from the Brazilian Association of Public Cleaning and Special Waste Companies (Abrelpe, 2022).

Following the solid waste management agenda, it is recorded that almost half of Brazilian municipalities (49.9%) dispose of their waste in dumps, with irregular and illegal deposits. In addition, 17.8 million Brazilians do not have garbage collection from their homes, and only 3.85% of waste is recycled, according to data from the Urban Cleaning Sustainability Index - ISLU, as prepared by the National Union of Urban Cleaning Companies - SELURB, in partnership with the consultancy firm PwC Brazil (Selurb, 2020).

Due to the disorder in urban waste management, in addition to the housing deficit and unemployment, in Brazil, the reality is that there are almost 2,970 dumps, where people are living and trying to make an income through the collection and sale of urban waste, in an obvious situation of social and climate vulnerability (ABRELPE, 2022).

In this sense, the recycling of this waste promotes urban adaptation to climate risks, through the removal of these people from their socioeconomic vulnerability and by ensuring their inclusion with adequate housing. The proposal, discussed here, aims to integrate Recycling into models of (i) urban adaptation to climate risks and tragedies, as well as (ii) greenhouse gas (GHG) mitigation.

In this context, recycling emerges as a key strategy to promote urban resilience and reduce the impact of climate change. Therefore, the objective was to measure the relevance of recycling in the urban city context, as well as its contribution to the processes of urban adaptation and mitigation of greenhouse gases, given social and climate vulnerability (IPCC, 2023). The article includes experiences obtained in two case studies and with the mapping of environmental and ecosystem services provided through recycling, which serve as a model for replication.

This article is structured with an Introduction where the problem and objective are presented initially. A Literature Review follows, where aspects of recycling and its importance are addressed. Then the Results and a Discussion to highlight the mitigation case studies and financing policies. Finally, the final considerations and references.

2. Literature Review

2.1 *Recycling as an Ecosystem Impact Environmental Service and Its Contribution to Building Climate-Resilient Cities*

Understanding Recycling as an environmental service that affects the ecosystem and has a real relevance for the construction of Climate Resilient Cities is the first challenge in this article. In this sense, it is valid to conceptualize environmental and ecosystem services and the permeability between them, to achieve an understanding of recycling concepts.

Ecosystem services, as well as their valuation, have been a recurring need due to the scalability of climate tragedies observed on the national scene, where anthropogenic actions are the main contributors, with social, economic, and environmental consequences and relevance, weakening the entire ecological system (Gomes *et al.*, 2018). Academics have contributed to a growth in the number of publications with an emphasis on ecosystem services, but the published works did not limit the continuity of the evolution of the concept, which remains without standardization and fluctuates between points of ecological or economic origin, within their approaches.

To structure this article and demonstrate the relationship between ecosystem services and recycling, the economic-ecological concept is taken as a basis. This concept takes into consideration the integration of sustainable objectives, social justice, and economic efficiency, in addition to the traditional objective of economic efficiency (Andrade and Romeiro, 2013).

For the same researchers, economic-ecological valuation is a way of assigning value to ecosystem services that have been developed within the theoretical current called Ecological Economics, insofar as it seeks to take into account the complex nature of ecosystems and the different values associated with them. This also includes the risks of potentially catastrophic irreversible losses of ecosystem structures and functions, taking into account the ecological, economic, and social sustainability of the maintenance and/or use of resources.

The Concept of Environmental Service is closely linked to the concept of Ecosystem Service, where the first concept delivers positive actions for the preservation of water bodies, carbon fixation, and soil and air preservation, through ducts that will guarantee this flow of ecosystem service.

The permeability of the concepts is such that certain authors treat them as synonyms, without losing the literary sense (Picharillo and Ranieri, 2019), but the same authors make clear the differences in the concepts when they state that Environmental Services are intrinsic to Ecosystem Services, however, Ecosystem Services do not depend on the Environmental Service to exist. Environmental Services are generated through human actions, while the Ecosystem Service stems from natural origins.

Given the permeability of the concepts, Recycling is part of the ecosystem function of the concept of economic-ecological valuation, given the delivery of a service, that promotes social inclusion, job, and income generation, as well as the preservation of natural resources (water, soil, and air), through the return of recyclable inputs to the production chain, replacing natural inputs.

Stimulating recycling and the practice of selective collection within the national territory is a concrete way to include and identify the environmental service provided by collectors of recyclable materials, as well as a mechanism to encourage payment for the environmental service provided to Brazilian Cities (Mello, 2019).

Payment for Environmental Services - PES, within the urban waste management of cities, is an economic tool that can be used to encourage the work of individual persons who collect waste and, consequently, recycle. PES is a demand of most individuals who collect waste in Brazil, who provide a relevant service to society by allowing recyclable materials to return to the production cycle, instead of being landfilled (Castro et al., 2020).

The economic-ecological valuation portrays the need to have a truly transdisciplinary approach to deal with the complexity of ecosystems and their contributions to human well-being, where it is necessary to unite efforts to face the degradation of natural capital, which is the main reason for the environmental tragedies experienced by Brazil (Andrade and Romeiro, 2013).

Recycling, as an environmental service with an ecosystem impact, has the quality of promoting transdisciplinary delivery, since it promotes the relationship between the public and private spheres, always with the presence of representatives of civil society, with the constant involvement of social, environmental, and economic factors.

In this sense, the governance of recycling within cities becomes more efficient when built by the same actors who perform the task, which makes the relationship between them more symmetrical (Giglio *et al.*, 2023).

Therefore, when recycling is present within cities, it can promote social economy and remove people from vulnerable conditions (Valderrama *et al.*, 2020).

The “stage” for the main actions and results promoted by recycling are Cities, where their challenges and opportunities are observed (Table 1).

Table 1. Challenges and Opportunities of Recycling in Cities

RECYCLING CHALLENGES		RECYCLING OPPORTUNITIES
Environmental Services provided by recyclable waste pickers	<ul style="list-style-type: none"> – Waste recycling (organic and inorganic); – Selective waste collection; – Reception and selection; – Screening; – Pressing, baling and storage; – Processing; – Transportation; – Commercialization of waste; – Solid waste management; – Environmental education. 	<ul style="list-style-type: none"> – The diversion of tons of recyclable waste from being improperly sent to landfills and dumps, promoting the economy of natural resources, the protection of water bodies, soil, and the atmospheric environment; – Socioeconomic inclusion of recyclable waste pickers, through the environmental service provided in cities, especially when this service is recognized and duly contracted by municipal public managers.
Landfill Closure	<ul style="list-style-type: none"> – Adaptation and Climate Mitigation. 	<ul style="list-style-type: none"> – Closure of open-air dumps, which are areas of socio-environmental vulnerability and targets for climate tragedies, with the social and economic inclusion of waste pickers living in these areas,
De-carbonization	<ul style="list-style-type: none"> – Climate Mitigation 	<ul style="list-style-type: none"> – Factory de-carbonization process, through the reduction of emissions of harmful gases to the ozone layer, when using recycled inputs to replace virgin raw material.

Source: Author (2023)

Thus, Recycling is present in the urban context, with the delivery of environmental and ecosystem services to Cities, which in turn contribute to the challenge of urban solid waste management. It is also concerned with landfill reduction, the socioeconomic inclusion of the workforce of recyclable waste pickers, de-carbonization of the industrial process, prevention of climate tragedies, and migration from the linear economy to a circular economy, thereby giving Cities the capacity to be resilient in the face of climate impacts.

2.2 The Climate Relevance of Recycling

Given the findings about Recycling with an ecosystem impact environmental service of relevance to Cities, we intend to discuss in this section the methodological perspectives of these services to face the climate crisis and the resilience of Brazilian Cities

The contributions presented here are based on the general orientation that, if on the one hand, recycling is recognized as a service to face the climate crisis, on the other hand, it is admitted that efforts must be made to refine and expand the results of recycling functionality to deliver sustainability. Job and income generation, the economy of natural resources, energy, and water, decarbonization of national industry, through waste recovery operations and processes, diverting them from landfills and promoting the closure of landfills, with the proper social and productive inclusion of people who live and work in them, in decent and operational recycling plants also constitute the suggestions to be considered.

The vast scientific evidence about human interference in the natural processes of regulation of the climate system, especially with GHG emissions from the burning of fossil fuels, as well as the impacts resulting from industrial activity, is a warning of the urgency around climate change that society is immersed in (IPCC, 2023).

In Brazil alone, climate tragedies derived from global warming, increasingly frequent and intense, have been and are being recorded. In 2023, three catastrophic events were recorded in different regions of Brazil (Table 2), as well as forecasts of new climatic extremes in the north and northeast regions:

Table 2. Climate tragedies Brazil – Year 2023 – Data and Forecasts

Regions	Type of Disaster	Deaths	Other Consequences	Forecasts
North Coast of S ão Paulo	– Flash Floods – Floods – Landslides – Burials from landslides	65		
Rio Grande do Sul	– Floods – Flooding – Burials from landslides	50		
Amazonas	– Drought – Threats to navigation – Threat of access to drinking water – Threatens aquatic life – Worsening of wildfires.		– Covered Manaus in Smoke – People isolated by the damage to navigation by sea/river – Manaus (AM) and Rio Branco (AC) declared a state of emergency. – Historical drought in the Rio Negro River.	–
North and Northeast				– Rainfall below the climatological average (historical average) – Temperatures above the historical average throughout the region in the coming months.

Sources: S ão Paulo (2023); Rio Grande Do Sul (2023); Amazonas Climate Panel (2023); and National Institute of Meteorology - INMET (2023).

The connection between extreme weather events and social vulnerability in part of the Brazilian territory, characterized by environmental and social inequalities, demands anticipatory governance and climate adaptation in the context of Brazilian cities (Travassos *et al.*, 2020).

Given the climate urgency that is now part of our world and strongly evidenced in our country, tools must be sought that deliver urgent solutions to face the Climate Crisis. Recycling, as an ecosystem environmental service, presents a wide variety of initiatives aimed at reducing risks and enhancing opportunities.

2.3 Recycling in Urban Adaptation Actions to Climate Risks and Tragedies

COP 27 (2022) was incisive in affirming the climate crisis in which the world is immersed, where we will no longer be able to avoid climate tragedies resulting from global warming. COP 27, in addition to seeking to renew the urgency of compliance with the Paris Agreement, an agreement that was promulgated in Brazil by Decree 9.073 of June 5, 2017 (BRAZIL, 2017), had as its focal point an alert to the growing energy crisis in the world. The conference demonstrated the record concentrations of greenhouse gases and the escalation of extreme weather events that are causing tragedies around the world and affecting, in the majority, countries, cities, regions, and people in situations of socio-environmental vulnerability, including Brazil.

Faced with the flagrant irreversibility of the effects of climate and environmental damage already part of our society, COP 27 ended with an agreement to create a financing mechanism to compensate vulnerable nations for losses and damages caused by climate disasters, showing that the processes of mitigating the environmental damage generated to our planet are failing (UN NEWS, 2022).

The failure of global climate action is the main threat facing society during the next decade, where denying the climate crisis due to droughts, fires, floods, resource scarcity, and species loss is no longer an option for the world (LOPES, 2022).

Adaptation and climate justice must integrate public policy planning so that they do not simply become ineffective concepts (TORRES *et al.*, 2021).

The activity of solid waste recycling, in the Brazilian reality, is directly linked to social factors, through the labor of recyclable waste pickers, who have been performing this environmental service in our country for years, when the appeal of sustainability did not yet exist. In this sense, these professionals are carrying out their activities and living in dump areas, areas that can be referred to as socio-environmentally vulnerable.

The social inclusion of this category through the valorization and payment for their environmental service (PES) provided to municipalities and society and considering, the dignity of their type of work, as well as technology and machinery now part of operational solid waste recycling plants, will be a "driving force" for the increase in the scale of national recycling. This will result in the adaptation and mitigation of greenhouse gas emissions in the industrial process (CASTRO *et al.*, 2020).

2.4 Connection of Studies

From the evaluation of the studies highlighted by the authors, it is clear that recycling is an environmental service with climate impact within the context of cities, in urban adaptation actions, and within the context of industry, with climate mitigation actions, which is why this article seeks to evaluate possible gaps and the need to produce new studies that seek to evaluate whether the increase in solid waste recycling carried out in Brazil will have the capacity to contribute to the reversal of the climate crisis situation in place, directly contributing to national reduction targets emissions, as well as preventing several lives from being lost due to new climate and environmental disasters that have been observed in our country.

3. Methodology

3.1 Research Flowchart

The Methodology followed a research flowchart (Figure 1), where the initial database was based on research by observing climate change and global warming "in loco", and by participating in two conferences of the parties on climate (COP 27) at the end of 2022, in Egypt and COP 28 at the end of 2023, in Dubai).

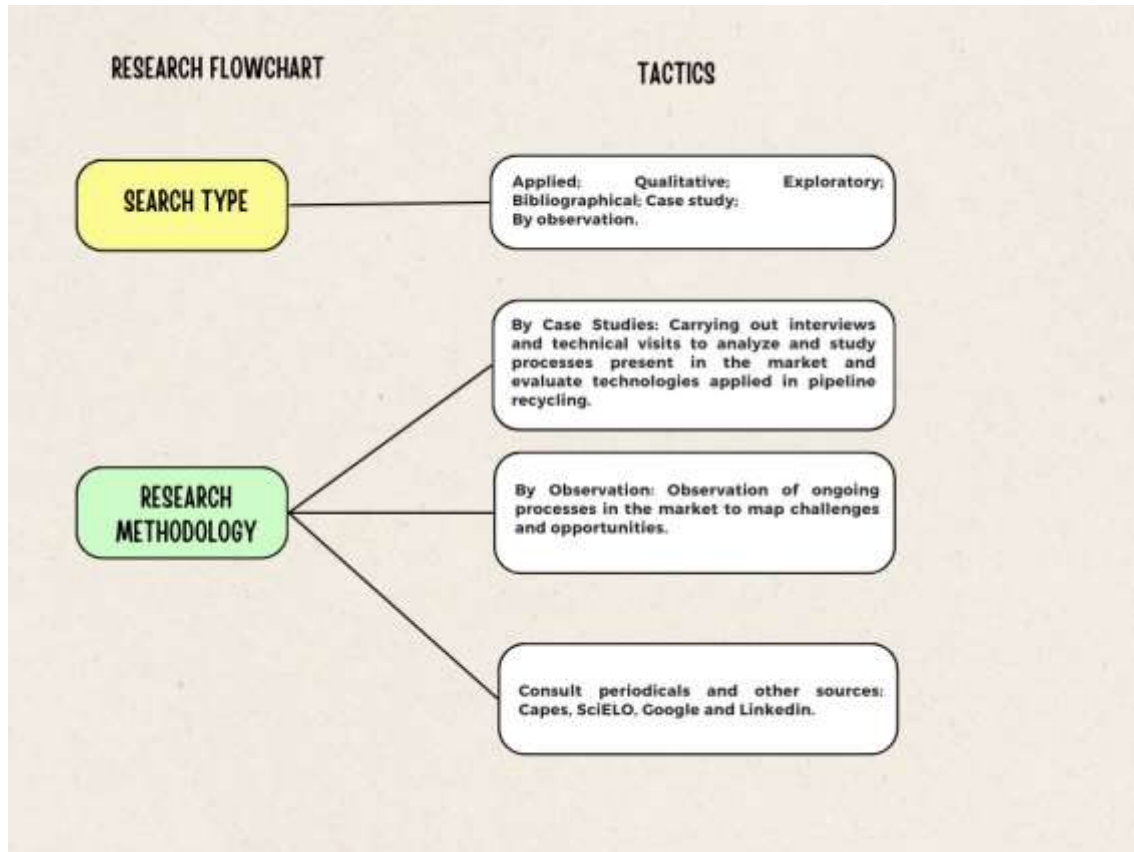


Figure 1. Survey flowchart

Source: authors (2024)

Data collection also took place within the two working groups (Consumption/Midstream and Social Issues of the Ministries), created by the Ministry of Foreign Affairs, focusing on the development of an international, legally binding instrument.

3.2 Periodic Consultations

The study was characterized as qualitative research, with a fundamental focus on understanding the phenomenon and its possible impact on the environment and cities. The method used was a literature review, so that the question of interest, the database to be analyzed was answered.

To this end, a strategy was adopted to ascertain the relevance of recycling within urban spaces, seeking to answer the following research questions: What are the challenges of recycling to contribute to the creation of climate-resilient cities? How can climate finance effectively deliver the opportunities pointed out by recycling?

To answer these questions, searches and research were carried out in 2022, 2023, and in the first months of 2024, to consider the articles published up to the moment of this research, in the scientific platform journals Capes and SciELO, among other sources. There was a combination of keywords, inclusion criteria, and the exclusion of articles to subsequently evaluate, synthesize, and interpret the data. The terms “recycling”; “environmental services”; “ecosystem services”; “climate adaptation”; “climate mitigation” “greenhouse gases – GHG” and “climate financing” were associated with the Boolean operators “AND” and “OR”. Legislation and regulations complemented the need for investigation.

From the articles that make up the database, seven of the Capes journals and two of the SciELO journals were included, totaling nine selected scientific articles (Figure 2).

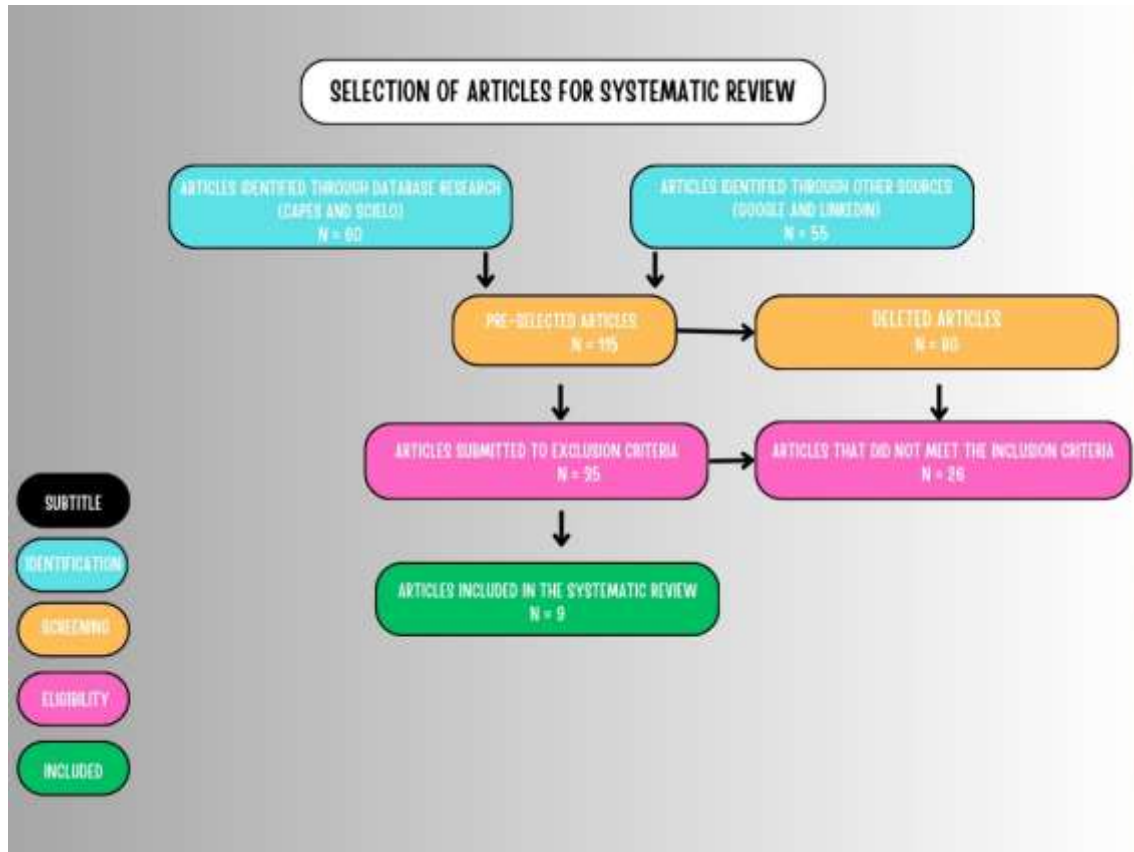


Figure 2. Screening of articles obtained from the journal research platforms Capes, and SciELO, among other sources, until the year 2024

Source: authors (2024)

After the search, as a first step, the articles were sorted and recorded on a spreadsheet so that the analysis could be guided. The information noted in this section included year of publication, author, journal, field of research, and reasons for inclusion or exclusion of the article.

From the record of the most general information of the articles, the titles, abstracts, and keywords of all identified articles were read and analyzed. This step aimed to ensure that articles met the inclusion criteria, that is, to discuss the relationship between recycling and climate change.

As for the exclusion criteria, studies conducted outside Brazil, review articles, and articles that were not available in full text in PDF format were not evaluated. After the screening, the next step included reading the articles in full, allowing other articles to be excluded according to the criteria.

3.3 Case Studies

Two case studies of the national industry were analyzed and highlighted:

- a) The scenario of recycling aluminum cans and the Case of the company "Ball";
- b) The plastic recycling scenario and the Case of the company "Braskem"

In both cases, the recycling of these materials and the impact on the value chain of these companies are diagnosed, as well as product life cycle analysis (LCA) and the risks and opportunities of these actions.

3.4 Financing

Closing the analysis, the financing of climate coping actions by recycling is addressed, where the guiding principles, legislation, and resolutions that cover the subject are invoked, offering alternatives for public policies that can value recycling as an environmental service in the ecosystem balance by integrating urban adaptation and mitigation of greenhouse gas emissions.

4. Results and Discussion

4.1 Case Studies of Recycling in Greenhouse Gas (GHG) Mitigation Actions

Thinking about Recycling involves thinking about ongoing actions and initiatives in our society, with short-term and medium-term impacts, which must and can be scaled. These impacts transcend decarbonization and promote social and climate justice, by generating employment and income, social inclusion, human dignity, saving natural resources, water, energy, and health promotion.

Certain segments of the industry chain have already measured the impacts of recycling on the decarbonization of their processes. These include the recycling of cans and plastic, which will be addressed in this article, through the traceability and highlighting of the impacts of recycling on the decarbonization process and climate resilience of the aluminum and plastic can industries (Cases Ball and Braskem), discussed below.

The scenario of recycling aluminum cans and the Case of the company "Ball"

The first case study to be highlighted is the recycling of aluminum cans, a segment that reached the 100% recycling mark in Brazil in 2022, according to a calculation carried out by the Brazilian Aluminum Association - ABAL in partnership with the Brazilian Association of Aluminum Can Manufacturers – Abralatas (ABAL, 2022).

The high recycling rate of cans in Brazil is a consequence of the economic value inherent to the material, as well as studies and investments applied to its value chain. In this sense, the analysis carried out in the value chain of the company Ball found that it generated 87% (or US\$13.37 billion) of its revenue from the sale of products made from recycled, recyclable, rechargeable, or reusable materials. These products include aluminum beverage cans (BALL, 2023).

Following the mapping of its value chain, the Ball Company identified the relevant risks and opportunities associated with its emissions, as well as developing impact reduction plans to involve partners in the chain to assist with climate mitigation actions. In 2021, the Ball Company included in its vision the goal of achieving a global recycling rate of 90% for cans, bottles, and beverage cups and an average of 85% of recycled content in its products (BALL, 2023).

The company, through its climate transition plan, sought to generate opportunities and engagement for *stakeholders* in the sense of the need for environmental actions and their benefits for the value chain, implementing recycling targets, combined with a reduction in GHG emissions by the primary aluminum industry and the reduction of its absolute emissions by 55% (Figure 3).

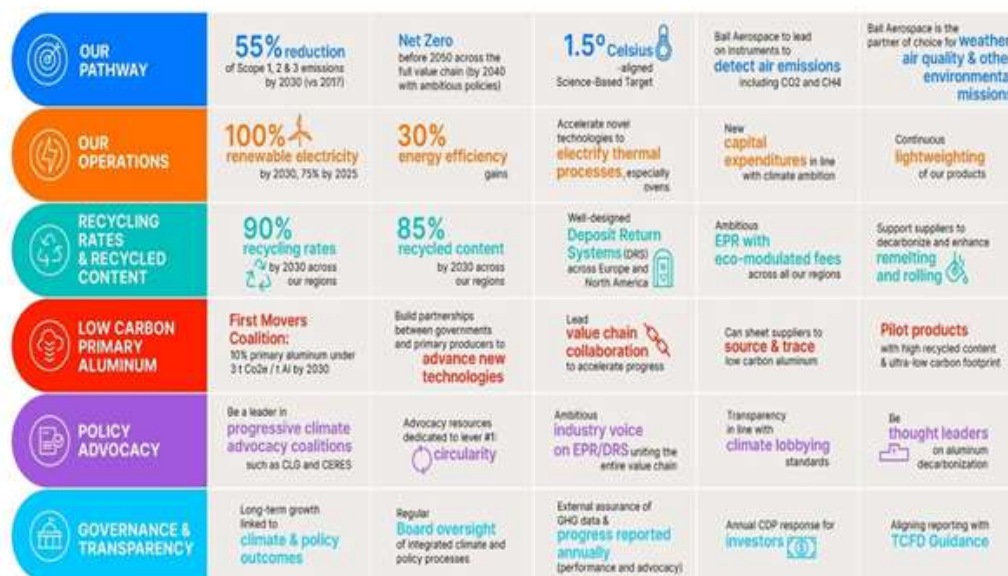


Figure 3. Summary of the Ball Company Climate Transition Plan

Source: Ball Corporation's - Climate Transition Plan (2023).

The pursuit of reducing emissions in the aluminum value chain helped this segment of the industry to be certain of the impacts of recycling on the decarbonization of its processes, as well as real impacts on the national climate mitigation scenario.

The plastic recycling scenario and the Case of the company "Braskem"

The second highlighted case study is that of plastic recycling, where it was measured through the description of the Life Cycle Assessment (LCA) of Post-Consumer Recycled Resins (PCR) produced in Brazil as carried out by the company Braskem, as well as the diagnosis of plastic recycling in Brazil and worldwide.

Unlike the reality of aluminum, plastic gives rise to serious apprehension at a global level due to its environmental impact, either due to the fossil origin of its original raw material, or due to contamination resulting from its irregular disposal. Plastic contamination is treated as a relevant threat to the environment, human health, and the economy, where greenhouse gas emissions associated with plastic must be limited to 15% of total emissions allowed by 2050 if humanity wants to keep global warming down to 1.5 °C (UNITED NATIONS ENVIRONMENT PROGRAMME - UNEP, 2023).

Seeking to change the serious situation in which it finds itself, Brazil is part of the Intergovernmental Negotiating Committee to develop a legally binding international instrument on plastic pollution, including within the marine environment. The purpose of the committee is the elaboration of a treaty to combat plastic pollution, including essential obligations, control measures, voluntary and/or legally binding approaches, and means of implementation (INTERNATIONAL SCIENTIFIC COUNCIL - ISC, 2023).

Despite the government effort, the industry has a share of responsibility in the search to reverse this situation. Braskem, a leader in the plastic production market in Brazil, triggered its HCV process, based on its Materiality Matrix, which analyzed the Risks of its business and alignment with the global trends of the UN 2030 Agenda and the Paris Agreement. The Life Cycle Assessment (LCA) became part of Braskem's sustainability strategy and a tool that allowed it to quantify its environmental impacts throughout the life cycle, guiding its actions and decisions towards reducing the environmental impacts derived from its operation (BRASKEM, 2023)

Specifically on the impact of recycled polypropylene (PP) and polyethylene (PE) resins, Braskem analyzed 24 contexts of the production chain that, grouped according to the recycled content and origin of the raw materials, reached four segments of recycled resins. The results were categorical in materializing that recycled resins contribute to resilience to positive climate change, presenting a carbon footprint up to 48% lower than virgin products of fossil origin. Given the positive results, the company aims to continue promoting recycling at the end of the plastic's useful life, as well as the production and expansion of its portfolio of products with recycled content (BRASKEM, 2023).

The plastic industry has been making efforts to increase recycling numbers (Figures 4 and 5).



Figure 4. Monitoring of mechanical recycling rates of post-consumer plastics in Brazil

Source: PICPLAST, 2021



Figure 5. Monitoring of mechanical recycling rates of post-consumer plastics in Brazil

Source: PICPLAST, 2021

Innovation with the creation of new products and the increase in the use of recyclable plastic input in the industry's production chain will reduce the carbon footprint and increase the numbers of plastic recycling in Brazil and worldwide.

4.2 Financing of Climate Action by Recycling

Brazil, through the National Policy on Climate Change, regulated by Law no. 12.187/2009 (BRAZIL, 2009), provided for the elaboration of sectoral plans with the inclusion of specific actions, indicators, and targets for reducing emissions and mechanisms for verifying their compliance.

To execute the sectoral plans in question, according to Decree No. 11.550, of June 5, 2023, the permanent Interministerial Committee on Climate Change - CIM was established, to monitor the implementation of public actions and policies under the scope of the federal Executive Branch related to the National Policy on Climate Change – PNMC (CIM, 2023).

The Chairman of the Interministerial Committee on Climate Change – CIM, through CIM Resolution No. 1 of September 14, 2023, provided for the update of the National Plan on Climate Change – Climate Plan, which included the preparation of several Sectoral Plans, including the City Mitigation Plan (item III) and the Waste Mitigation Plan (item VII) (Table 3).

Table 3. CIM Resolution No. 1 of September 14, 2023.

Art. 3 The Sectoral Mitigation Plans must contain at least:
I – sectoral context of mitigation;
II – sectoral mitigation objectives and priorities;
III – sectoral mitigation targets for 2030 and indicative targets for 2035;
IV – specific actions, programs, and measures to achieve the goals, including the respective goals, indicators, costs, sources of financing, and other means of implementation;
V – proposals for revision of the sectoral normative framework aiming at alignment with the objectives, priorities, and sectoral mitigation goals; and
VI – governance for the management, monitoring and evaluation of the sector plan, including mechanisms for participation and transparency.
Sole Paragraph. At least the following Sectoral Mitigation Plans will be prepared:
I – Change in land use and forests;

II - Agriculture and Livestock
III – Cities, including urban mobility;
IV – Energy, including electricity and fuels;
V – Industry;
VI – Mining;
VII – Waste; and
VIII – Transportation.

Source: Interministerial Committee on Climate Change – CIM, 2023.

Brazilian Cities have been the main victims of climate tragedies and, thus, Sectoral Plans should include ways to face environmental threats where residents and critical infrastructure of cities are inserted (SOLECKI et al., 2021).

The Sendai Framework for Disaster Risk Reduction 2015-2030, adopted at the Third United Nations World Conference in Sendai, Japan, established principles whose main responsibility is to prevent and reduce disaster risk, including through cooperation (SOUTHERN AFRICA DEVELOPMENT COMMUNITY - SADC, 2015).

Table 4. Sendai Framework for Disaster Risk Reduction 2015-2030 Guiding Principles

- Shared responsibility between central government and national authorities, sectors, and stakeholders as appropriate to national circumstances;
- Protection of people and property, promoting and protecting all human rights, including the right to development;
- Activation of the entire society;
- Full activation of all state institutions of an executive and legislative nature at the national and local levels;
- Empowerment of local authorities and communities through resources, incentives, and decision-making responsibilities, as appropriate;
- Decision-making should be inclusive and risk-informed, using a multi-risk approach;
- Coherence in different sectors in disaster risk reduction and sustainable development policies, plans, practices, and mechanisms;
- Accounting for local and specific characteristics of catastrophe risks in determining measures to reduce risks;
- Address the underlying risk factors in a cost-effective manner through investment, rather than relying primarily on post-disaster response and recovery;
- “Build better” to prevent new disasters and reduce existing disaster risks;
- The quality of global partnership and international cooperation must be effective, meaningful and strong;
- Support from developed countries and partners to developing countries should be tailored according to the needs and priorities that identify them.

Source: SADC (2025)

The Sendai Framework Guiding Principles act as a route for coordinated and shared actions between various spheres of governments, authorities, sectors, and stakeholders in disaster risk prevention and reduction. It is noted that the Sendai Framework is inspired by the concept of Social Capital, where Robert Putnam describes it as a set of social aspects, such as relationship networks, norms, and trust that allows action and cooperation for mutual benefit (PISTORE, 2013)

Based on the principles and concepts outlined, it is noted that climate responses within the dynamics of Brazilian cities will only happen through the cooperation of several actors, in various instances of action and, concerning the search for climate financing, due to the complexity of the actions to be carried out. These actors will not be limited to the federal, state, and municipal financial spheres, but rather to international sources such as Green Climate Funds that target their deliveries in large-scale climate adaptation and mitigation projects (SOLECKI et al., 2021).

It is relevant that climate adaptation and mitigation projects, which have recycling as an executive tool within the reality of Brazilian cities, are structured through a sectoral plan for cities and recycling, respecting items III and VII, of article 3, of CIM Resolution No. 1 of September 14, 2023. These items were subsequently part of the update of the National Plan on Climate Change – Climate Plan (CIM, 2023).

As an example of a municipal impact climate-structuring project, there is the *case* of Mexico City which, in 2016, launched a green obligation initiative at the municipal level worth one billion Mexican pesos to finance water supply, sustainable transport, and energy efficient infrastructures (EUROPEAN PARLIAMENT, 2023).

The European Parliament is seeking to regulate the green bond market to support climate- or environment-related projects and to finance or refinance investments, projects, expenditures, or assets that help address climate and environmental issues. The Parliament also claims that the European and global green bond markets grew by an average of 50% per year between 2015-2020 and believes that market regulation will boost the market for high-quality green bonds to meet the targets set out in the Paris Agreement and the European Green Deal (EUROPEAN PARLIAMENT, 2023).

As a synthesis of these actions, Figure 6 is presented. It is a systematization of procedures that culminate in mitigation and climate adaptation actions.

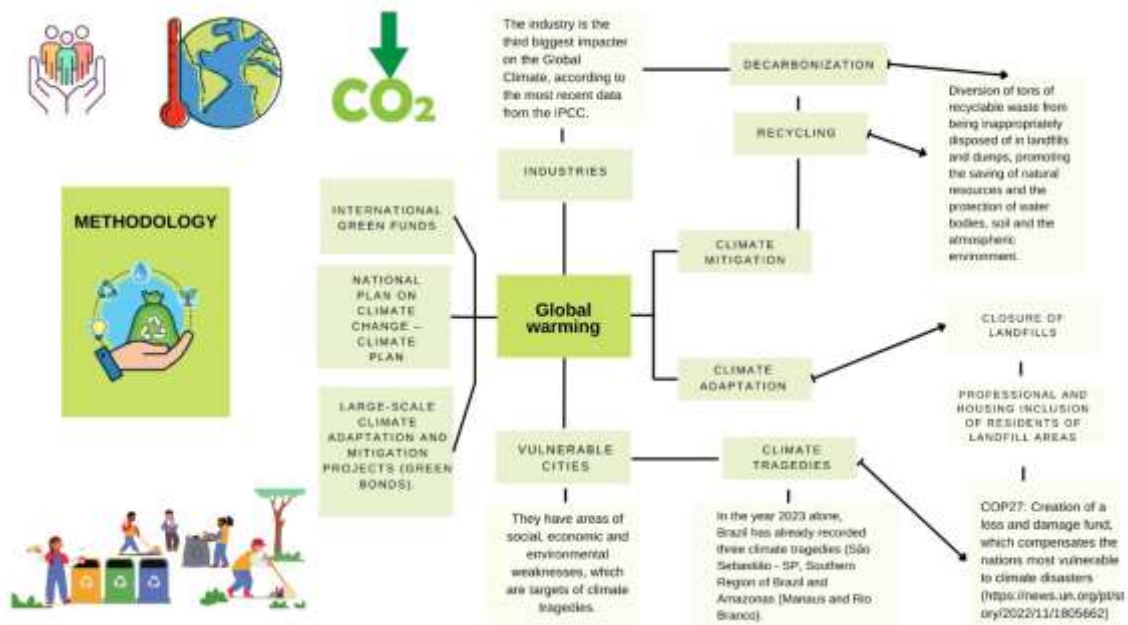


Figure 6. Operational procedures for climate mitigation and adaptation through recycling

Source: Author (2023)

The same movement must take place in Brazil, with the regulation of the Green Bond market and the concomitant launch of a Green Bond Pro Cities and Recycling, ensuring regional deliveries of climate adaptation and mitigation, in the form of Table 1 of this article, to meet Brazilian climate goals. The Regulation of Brazilian Green Bonds will generate legal certainty for the implementation of investment financial relations, in large-scale climate adaptation and mitigation projects, such as that in Mexico City, as well as opening a market for quality green bonds, according to the market desired by the European Parliament.

5. Final Considerations

This article aimed to analyze the relevance of recycling in cities and its relationship with the climate context, in proportion to the environmental ecosystem impact service delivered within the urban context, as well as the role played in building climate-resilient cities and reducing carbon emissions.

The climate mitigation actions promoted by recycling take place within the manufacturing context, through industrial decarbonization, when it promotes the return of recycled inputs to the production chain, replacing natural inputs, alleviating the overload of the planet, as well as saving water and energy used throughout the industrial flow. On the other hand, the climate adaptation actions promoted by recycling are reflected in the urban dynamics of cities, through the payment for environmental services, the implementation of selective collection, and the socioeconomic inclusion of urban solid waste collectors, in dignified operations and recycling plants, enabling their maintenance and moving them away from open dump areas. The data and the highlighting of information showed the benefits and urban actions promoted by recycling, which translate into climate adaptation and mitigation actions.

The results indicate that recycling plays a crucial role in reducing carbon emissions in urban areas by decreasing the need to produce new materials from virgin natural resources. In addition, recycling contributes to the sustainable management of urban and industrial waste by minimizing the amount of waste sent to landfills and reducing soil and water pollution.

Recycling was presented as an environmental service with ecosystemic repercussions that, in an integrated way, promote adaptation to climate change and the reduction of socio-environmental vulnerabilities in the urban context, increasing our country's recycling numbers, with job and income generation, social, urban, housing inclusion, decarbonization of the industrial process, thereby collaborating with Brazil to achieve its climate goals.

It is concluded that the findings in this study are in line with academic concepts and principles, such as the Sendai Framework Guiding Principles (SADC, 2015) and the Concept of Social Capital (PUTNAM, 1996). These demonstrate how urban actions promoted by Climate Recycling materialized through the effort and cooperation of various social actors, the construction of public standards, and organizational commitments of industry segments, in favor of the climate dynamics of our country.

Therefore, further efforts are recommended to demonstrate the relevance of recycling in climate adaptation and mitigation, to provide data for the control, refinement, and expansion of these processes, as a way of migrating from the current (linear) consumption and disposal economy to an inclusive and resilient (circular) economy. Thinking about recycling is to think also about sustainability, governance, and job and income generation, saving of natural resources, energy, and water. This can happen through operations and processes that can deliver waste recovery, diverting them from landfills and promoting the closure of open dumps, with the proper social and productive inclusion of people who live and work in them, in decent and operational recycling plants.

In addition, integrating recycling into urban adaptation and GHG mitigation strategies presents several challenges and opportunities, and is essential for building climate-resilient and long-term sustainable cities. Effective selective collection policies, payments for environmental services, incentives and encouragement for industries that run and encourage recycling, and climate finance are essential to promote recycling and create more sustainable cities.

Finally, by adopting policies and practices that promote recycling, cities can reduce their carbon emissions, minimize the environmental impact of waste, and promote the well-being of urban communities. Investing in recycling not only benefits the environment but also boosts economic and social development, creating more inclusive and sustainable cities for all, where climate finance will effectively deliver the opportunities identified in this article.

Acknowledgments

We would like to express our sincere gratitude to all those who contributed to the completion of this study. Special thanks to my advisor and co-author, Antônio Pasqualetto, whose guidance and insights were invaluable throughout the research process.

Special recognition goes to the company Braskem, in the person of the Director of Circular Economy for South America, Fabiana Quiroga, and to the company Ball, in the person of the Former Director and Senior Sustainability Manager, Estevão Braga, who contributed public data to carrying out the case studies in this article, whose collaboration was essential to obtain the results presented.

Authors' contributions

Luciana Figueras was responsible for data collection and writing the manuscript. The Prof. Antônio Pasqualetto reviewed it. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of Sciedu Press.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

Open access

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

References

- Amazonas Climate Panel. *Monitoring and actions to combat and prevent climatic factors in the Amazon*. Retrieved Nov. 6, 2023, from <https://www.paineldoclima.am.gov.br/>
- Andrade, D. C., & Romeiro, A. R. (2013, July). Valora ção de servi ços ecossist êmicos. *Sustainability in Debate*, 4(1), 43-58. <https://doi.org/10.18472/sustdeb.v4n1.2013.9199>
- Associa ção Brasileira De Empresas De Limpeza P ública E Res útuos Especiais – ABRELPE. *Panorama dos Res útuos S ãidos 2022*. Retrieved Nov. 5, 2023, from <https://abrelpe.org.br/panorama/>
- Associa ção Brasileira Do Alum ínio – ABAL. *Índice e reciclagem de latas de alum ínio para bebidas atingem marca recorde de 100%*. Retrieved June 6, 2023 from, <https://abal.org.br/noticia/indice-de-reciclagem-de-latas-de-aluminio-para-bebidas-atinge-marca-recorde-de-100>
- BALL. *Ball Corporation Releases Climate Transition Plan and 2022 Annual Combined Financial and Sustainability Report*. MAR 16 2023. Retrieved Nov. 4, 2023, from <https://www.ball.com/newswire/article/124168/ball-corporation-releases-climate-transition-plan-and-2022-annual-combined-financial-and>
- BALL. *Climate Leadership*. Retrieved Nov. 4, 2023, from <http://www.ball.com/sustainability/climate-leadership>
- Brazil. *Decree No. 9,073/2017 - Enacts the Paris Agreement under the United Nations Framework Convention on Climate Change*, celebrated in Paris, on December 12, 2015, and signed in New York, on April 22, 2016. Retrieved Nov. 6, 2023, from https://www.planalto.gov.br/ccivil_03/_Ato2015-2018/2017/Decreto/D9073.htm
- BRASKEM. *Avalia ção de Ciclo de Vida*. Retrieved Nov. 4, 2023, from <https://www.braskem.com.br/acv>
- BRASKEM. *Braskem apresenta ao mercado novas solu ções de PVC reciclado*. Retrieved June 16, 2023, from <https://www.braskem.com.br/wenew/noticia/braskem-apresenta-ao-mercado-novas-solucoes-de-pvc-reciclado>
- Brazil. *Institui a Pol ítica Nacional sobre Mudan çã do Clima – PNMC e dá outras provid ências*. Retrieved Nov. 6, 2023, from http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/112187.htm
- BRAZIL. *Disp õe sobre o Comit ê Interministerial sobre Mudan çã do Clima*. Retrieved Nov. 6, 2023, from <https://legislacao.presidencia.gov.br/atos/?tipo=DEC&numero=11550&ano=2023&data=05/06/2023&ato=3b0ETQ610MZpWT94a>

- Castro, A. M. R. C. De, Coimbra, E. C. L., & Jacovine, L. A. G. (2020, June). Pagamento por serviços ambientais a catadores. *Revista em Extensão*, 19(1), 4-19. <https://doi.org/10.14393/ree-v19n12020-51676>
- COP 27. (2022). *Sharm El-Sheikh Conference on Climate Change*. Retrieved June 23, 2023, from <https://www.unep.org/pt-br/events/conference/conferencia-de-sharm-el-sheikh-sobre-mudanca-climatica-unfccc-cop-27>
- Dos Santos, A. de C., & Pedroso Junior, N. N. (2021, November). Mitigation and adaptation of cities to climate change: socio-environmental vulnerabilities and legal conflicts in the protection of urban Permanent Preservation Areas in Brazil. *Revista de Direito da Cidade*, 13(4), 1720-1739. <https://doi.org/10.12957/rdc.2021.61081>
- European Parliament. *Green bonds: Greater transparency, no eco-whitening*. Retrieved Oct. 30, 2023, from <https://www.europarl.europa.eu/news/pt/headlines/society/20230928STO06003/obrigacoes-verdes-maior-transparencia-sem-ecobranqueamento>
- Giglio, E., et al.. (2023, April). The governance of E-waste recycling networks: Insights from São Paulo City. *Waste Management*, 161, 10-16. <https://doi.org/10.1016/j.wasman.2023.02.027>
- Gomes, A. dos S., Dantas Neto, J., & Silva, V. F. (2018, May). Serviços Ecosistêmicos: Conceitos e Classificação [Ecosystem Services: Concepts and Classification]. *Revista Ibero-Americana de Ciências Ambientais*, 9(4), 12-23. <https://doi.org/10.6008/cbpc2179-6858.2018.004.0002>
- Intergovernmental Panel on Climate Change - IPCC. *Climate Change 2022: impacts, adaptation and vulnerability. Working group ii contribution to the sixth assessment report of the intergovernmental panel on climate change* [H.-O. Pörtner, DC Roberts, M. Tignor, ES Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022. 3056 p. <https://doi.org/10.1017/9781009325844>
- Interministerial Committee on Climate Change – CIM. *CIM Resolution No. 1 of September 14, 2023*. Retrieved Nov. 4, 2023, from <https://www.lex.com.br/resolucao-cim-no-3-de-14-de-setembro-de-2023/>
- International Scientific Council - ISC. *The ISC at the second session of the Intergovernmental Negotiating Committee on Plastic Pollution*. Retrieved June 24, 2023, from <https://council.science/pt/current/blog/the-isc-at-the-second-session-of-the-intergovernmental-negotiating-committee-on-plastic-pollution/>
- Lopes, M. A. *Descarbonização e circularidade: respostas dos sistemas alimentar e agroindustrial aos Objetivos de Desenvolvimento Sustentável*. Brasília, DF: Embrapa Agroenergia, 2022.
- Mello, D. P. de. (2019). *Pagamento por serviços ambientais urbanos como instrumento de empoderamento dos catadores de materiais recicláveis*. Master's Dissertation in Development and Environment — Federal University of Pernambuco, Recife, 2019. Retrieved June 23, 2023, from <https://repositorio.ufpe.br/handle/123456789/37938>
- National Institute of Meteorology – INMET. Retrieved Nov. 6, 2023, from <https://portal.inmet.gov.br/>
- Onu News. *COP 27 closes with agreement on losses and damages: “A step towards justice”, says the UN chief*. United Nations. Retrieved Oct. 30, 2023, from <https://news.un.org/pt/story/2022/11/1805662>
- Picharillo, C., & Ranieri, V. E. L. (2019, November). Payment for environmental services: guidelines for identifying priority areas focusing on biodiversity. *Ambiente & Sociedade*, 22, 1590-1809. <https://doi.org/10.1590/1809-4422asoc201703033vu201913ao>
- Pistore, A. (2013, April). Genealogia Conceitual do Capital Social nas Perspectivas de Bourdieu, Coleman e Putnam. *A Economia em Revista - aere*, 21(1), 38. <https://doi.org/10.4025/aere.v21i1.14358>
- Plano De Incentivo A Cadeia Do Plástico - PICPLAST. *Monitoramento dos índices de reciclagem mecânica de plásticos pós-consumo no Brasil*. Retrieved Nov. 6, 2023, from https://www.picplast.com.br/portal/picplast/content/pdf/Pesquisa_reciclagem_2021.pdf
- Rio Grande Do Sul, State Government. *Após identificação de corpo, chega a 50 o número de mortos nas enchentes do Vale do Taquari*. Retrieved Nov. 1, 2023, from <https://estado.rs.gov.br/12h-apos-identificacao-de-corpo-chega-a-50-o-numero-de-mortos-nas-enchentes-do-vale-do-taquari>

- Rosin, J. A. R. G., & Teixeira, M. A. (2013). A Política de desenvolvimento urbano: os programas de regularização fundiária em APP urbanas e o desafio de implementação do direito à cidade. *Periódico eletrônico Fórum Ambiental da Alta Paulista*. 9(5), 216-235.
- SADC. *Disaster risk management information management system - DRM IMS*. Retrieved Oct. 30, 2023, from <https://drmims.sadc.int/sendai-framework/sendai-framework-for-drr>
- São Paulo, Governo Estadual. *Situação e ações de apoio no Litoral Norte*. Retrieved Nov. 6, 2023, from <https://www.saopaulo.sp.gov.br/spnoticias/boletim-situacao-e-aco-es-de-apoio-no-litoral-norte-1o-3-18h/>
- Sindicato Nacional Das Empresas De Limpeza Urbana – SELURB. *Índice de Sustentabilidade da Limpeza Urbana 2020 - ISLU*. Retrieved Nov. 5, 2023, from <https://selur.org.br/wp-content/uploads/2021/05/ISLU-2020-a.pdf>
- Solecki, W., Ramos, G. C. D., Roberts, D., Rosenzweig, C., & Walsh, B. (2021, February). Accelerating climate research and action in cities through advanced science-policy-practice partnerships. *Urban Sustainability*, 1(1), 1-3. <https://doi.org/10.1038/s42949-021-00015-z>
- Southern Africa Development Community - SADC. *Disaster risk management information management system - DRM IMS*. Retrieved Oct. 30, 2023, from <https://drmims.sadc.int/sendai-framework/sendai-framework-for-drr>
- Torres, P. H. C., et al.. (2021). Justiça climática e as estratégias de adaptação às mudanças climáticas no Brasil e em Portugal. *Estudos Avançados*, 35(102), 159-176. Retrieved March 16, 2024, from <https://doi.org/10.1590/s0103-4014.2021.35102.010>
- Travassos, L., et al.. (2020). Why do extreme events still kill in the São Paulo Macro Metropolis Region? Chronicle of a death foretold in the global south. *International Journal of Urban Sustainable Development*, 1-16. <https://doi.org/10.1080/19463138.2020.1762197>
- United Nations Environment Programme - UNEP. *O que esperar do início das negociações para acabar com a poluição plástica*. Retrieved June 24, 2023, from <https://www.unep.org/pt-br/noticias-e-reportagens/reportagem/o-que-esperar-do-inicio-das-negociacoes-para-acabar-com-poluicao>
- Valderrama, C. F., et al.. (2020). Analysis of the Recycling Sector in Intermediate Cities. Study Case – Neiva, Colombia. *INGENIERÍA Y COMPETITIVIDAD*, 22(2), 1-10. <https://doi.org/10.25100/iyc.v22i2.6252>